US009306471B2

(12) **United States Patent**
Li

(10) **Patent No.:** **US 9,306,471 B2**
(45) **Date of Patent:** **Apr. 5, 2016**

(54) **MICRO INVERTER OF SOLAR POWER SYSTEM AND METHOD OF OPERATING THE SAME**

(71) Applicant: **Delta Electronics, Inc.**, Taoyuan County (TW)

(72) Inventor: **Sheng-Hua Li**, Taoyuan County (TW)

(73) Assignee: **DELTA ELECTRONICS, INC.** (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 299 days.

(21) Appl. No.: **14/165,992**

(22) Filed: **Jan. 28, 2014**

(65) **Prior Publication Data**

US 2015/0085542 A1 Mar. 26, 2015

(30) **Foreign Application Priority Data**

Sep. 26, 2013 (TW) .... 102134715 A

(51) **Int. Cl.**

H02M 7/44 (2006.01)
H02M 1/32 (2007.01)
H02J 3/38 (2006.01)
H02M 1/00 (2007.01)

(52) **U.S. Cl.**

CPC ***H02M 7/44*** (2013.01); ***H02J 3/383*** (2013.01); ***H02M 1/32*** (2013.01); *H02J 3/385* (2013.01); *H02M 2001/007* (2013.01)

(58) **Field of Classification Search**

CPC ... H02M 1/32; H02M 7/44; H02M 2001/007; G05F 1/66; G05F 1/67

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,081,104 A * 6/2000 Kern H02J 9/065 320/101
6,590,793 B1 * 7/2003 Nagao H02J 7/35 323/222
8,472,220 B2 * 6/2013 Garrity H02M 7/46 307/45
9,143,082 B2 * 9/2015 Itako G05F 1/67
2009/0284998 A1 * 11/2009 Zhang G05F 1/67 363/55
2009/0316447 A1 * 12/2009 Kim G05F 1/67 363/37
2010/0157632 A1 * 6/2010 Batten H02M 7/4807 363/74
2011/0134668 A1 * 6/2011 Cho G05F 1/67 363/78
2011/0309684 A1 * 12/2011 Song H02J 3/383 307/87
2012/0062044 A1 * 3/2012 Wagoner H02J 3/38 307/151
2012/0205974 A1 * 8/2012 McCaslin H02J 3/385 307/18
2012/0235486 A1 * 9/2012 Li H02J 3/385 307/64

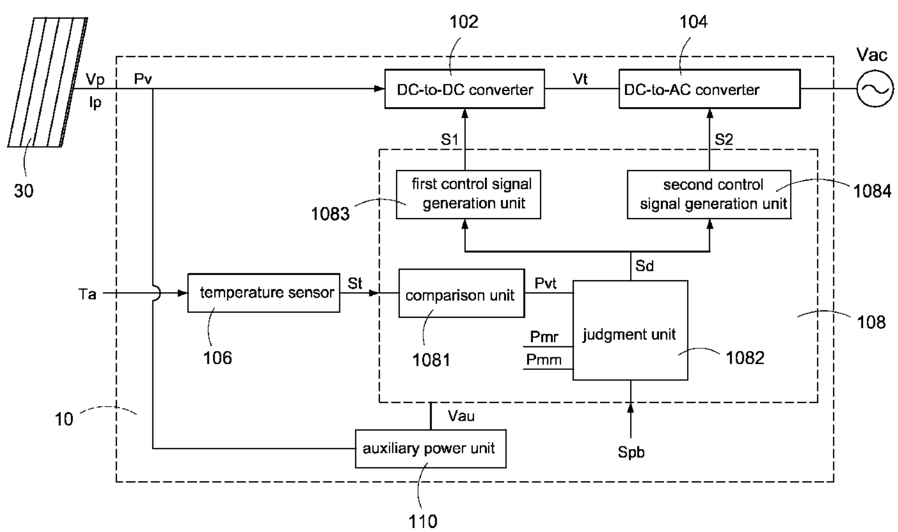
(Continued)

Primary Examiner — Timothy J Dole
Assistant Examiner — Yusef Ahmed
(74) *Attorney, Agent, or Firm* — Hauptman Ham, LLP

(57) **ABSTRACT**

A method of operating a micro inverter of a solar power system includes following steps: First, an output power value of a solar photovoltaic module is acquired. Afterward, it is to judge whether the micro inverter executes a power boosting mode. If the power boosting mode is executed, a maximum output power of the micro inverter is boosted from a rated output power value to a maximum output power value. Finally, it is to judge whether the output power value of the solar photovoltaic module is greater than the maximum output power value. If YES, the maximum output power value is outputted from the micro inverter.

14 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0319640 A1* 12/2012 Park G05F 1/67 320/101
2013/0027993 A1* 1/2013 Tan H02M 7/515 363/40
2013/0027997 A1* 1/2013 Tan G05F 1/67 363/95
2013/0234518 A1* 9/2013 Mumtaz H02J 3/40 307/46
2014/0112041 A1* 4/2014 Collin H02J 3/383 363/123
2014/0218985 A1* 8/2014 Yu H02M 7/537 363/97
2015/0002127 A1* 1/2015 Huang G05F 1/67 323/311
2015/0069840 A1* 3/2015 Teo G05F 1/67 307/52
2015/0236589 A1* 8/2015 Baba H02M 3/158 307/82
2015/0270787 A1* 9/2015 Fujisaki H02M 1/08 363/41
2015/0311800 A1* 10/2015 Katayama H02M 3/158 323/235

* cited by examiner

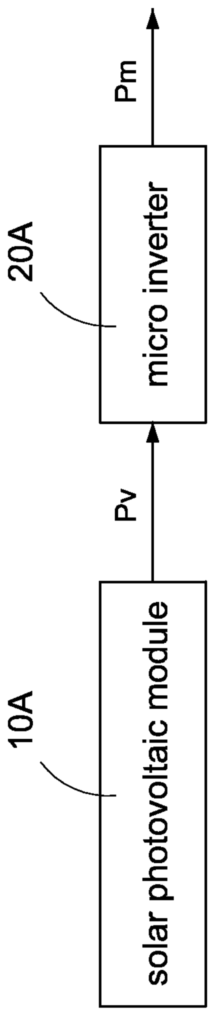


FIG.1
(Related Art)

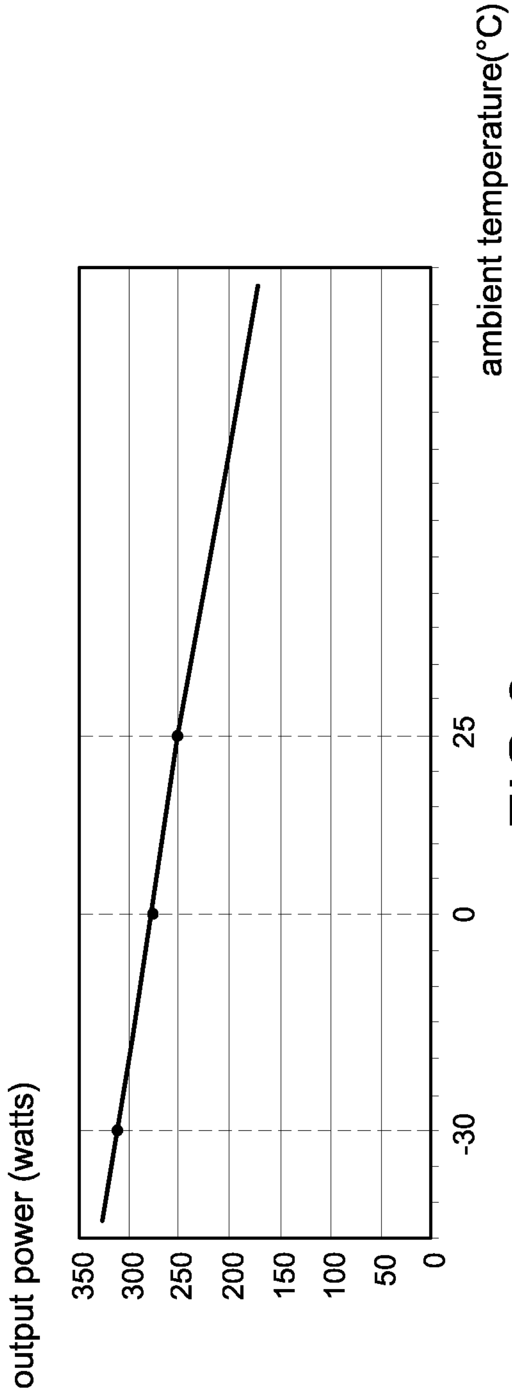


FIG.2
(Related Art)

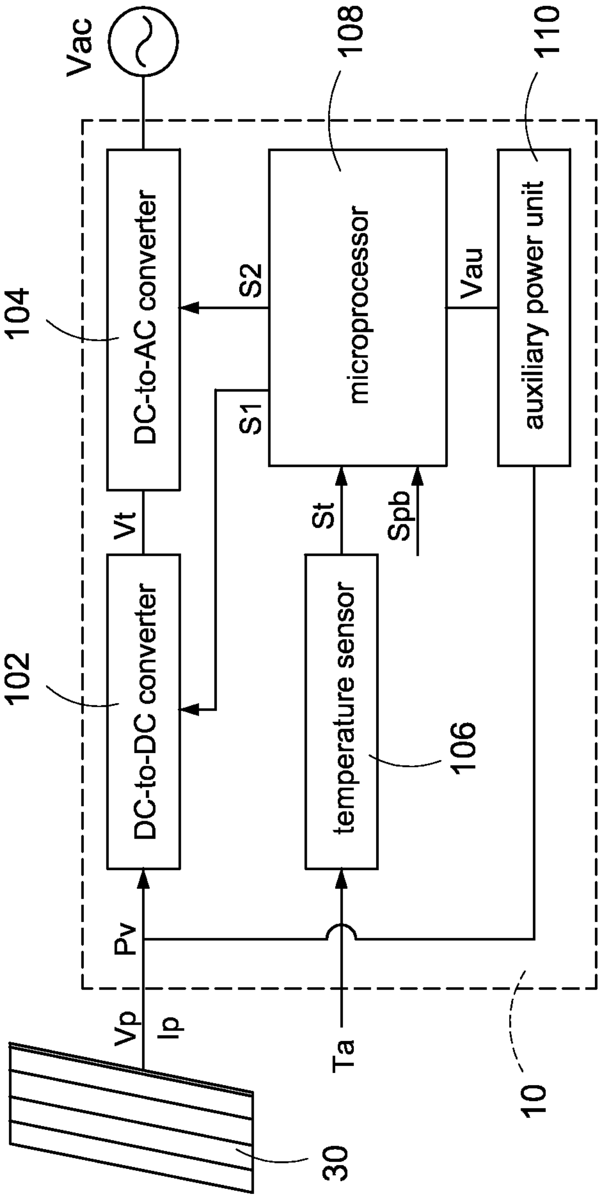

Vac
108
110
104
DC-to-AC converter
S2
microprocessor
Vau
auxiliary power unit
S1
Vt
St
Spb
102
DC-to-DC converter
temperature sensor
106
Pv
Vp
Ip
Ta
10
30

FIG.3

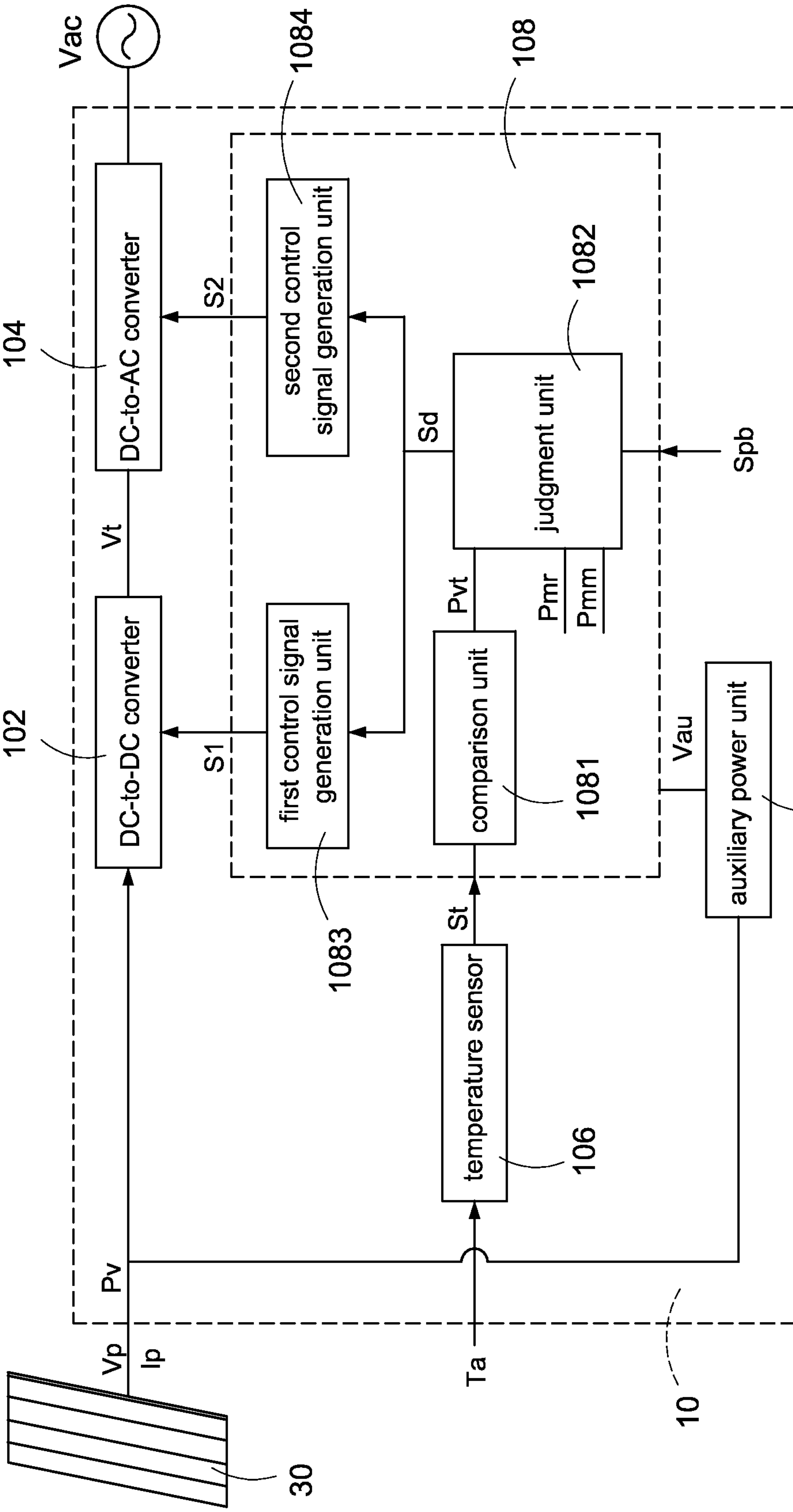

Vac
1084
108
104
DC-to-AC converter
S2
second control signal generation unit
1082
Sd
judgment unit
Spb
Vt
Pvt
Pmr
Pmm
102
DC-to-DC converter
S1
first control signal generation unit
comparison unit
1081
Vau
auxiliary power unit
110
St
1083
temperature sensor
106
Pv
Vp
Ip
Ta
10
30

FIG.4

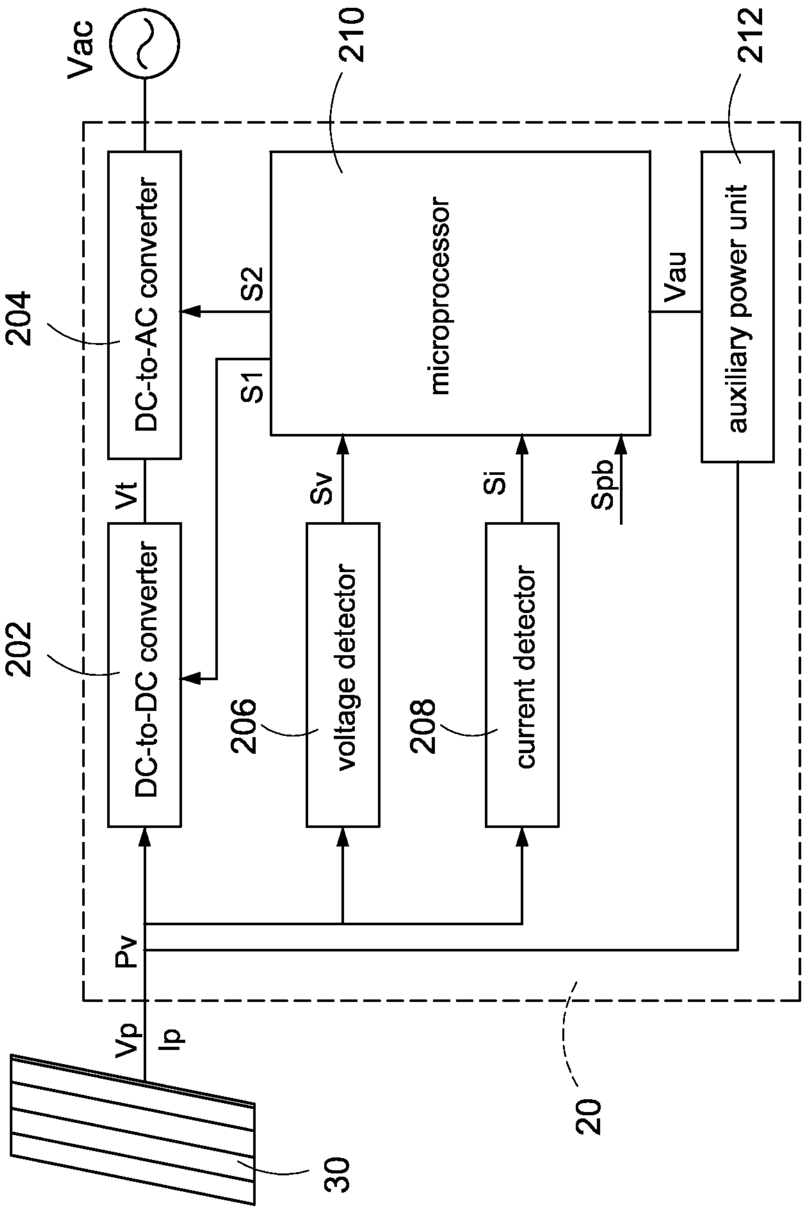
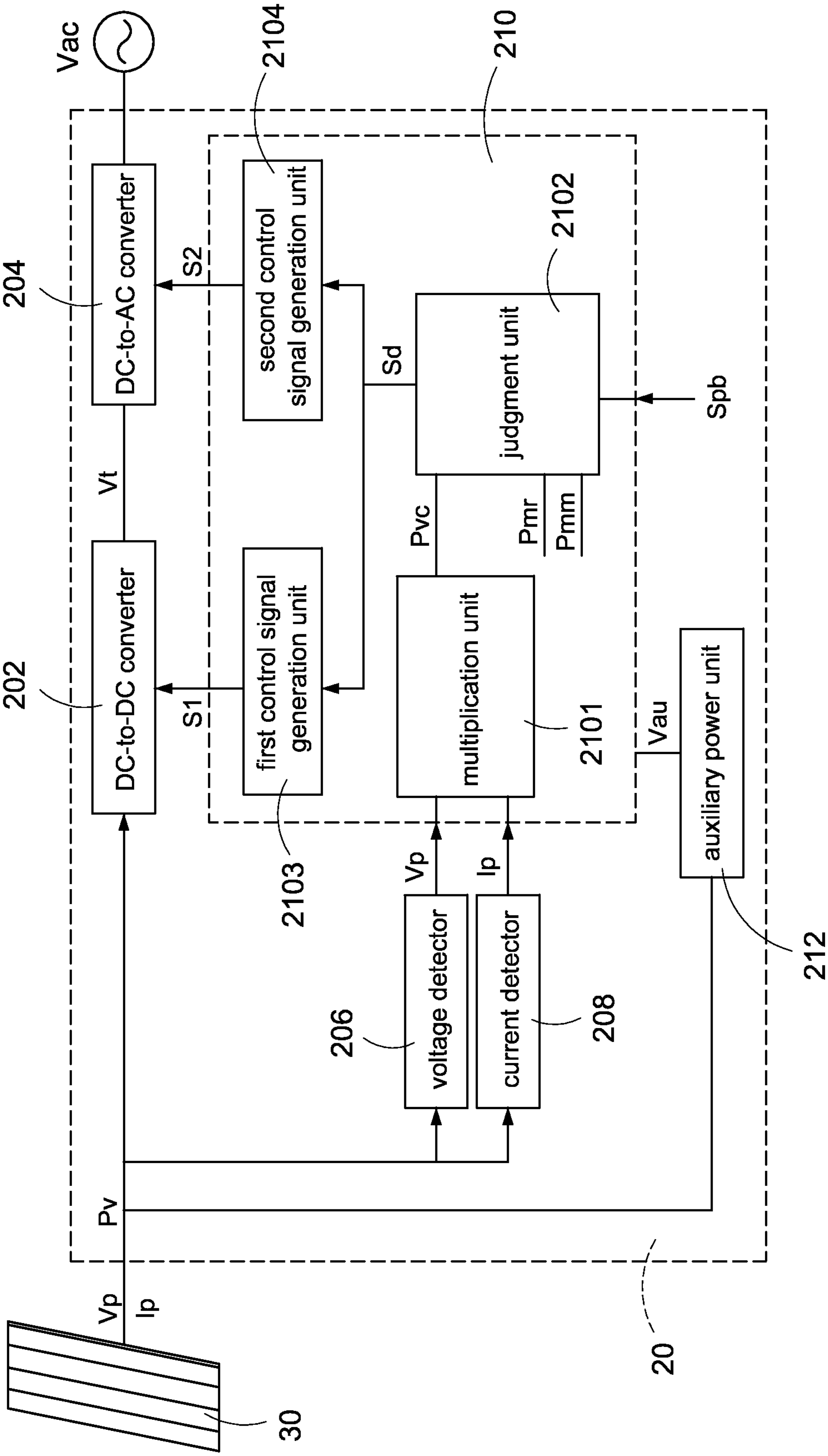

Vac
210
212
204
202
206
208
20
30
DC-to-AC converter
DC-to-DC converter
microprocessor
auxiliary power unit
voltage detector
current detector
S1
S2
Vau
Vt
Sv
Si
Spb
Pv
Vp
Ip

FIG.5



Vac
DC-to-AC converter
204
S2
second control signal generation unit
2104
210
judgment unit
2102
Sd
Spb
Pvc
Pmr
Pmm
Vt
DC-to-DC converter
202
S1
first control signal generation unit
2103
multiplication unit
2101
Vau
auxiliary power unit
212
Vp
Ip
voltage detector
206
current detector
208
Pv
20
30

FIG.6

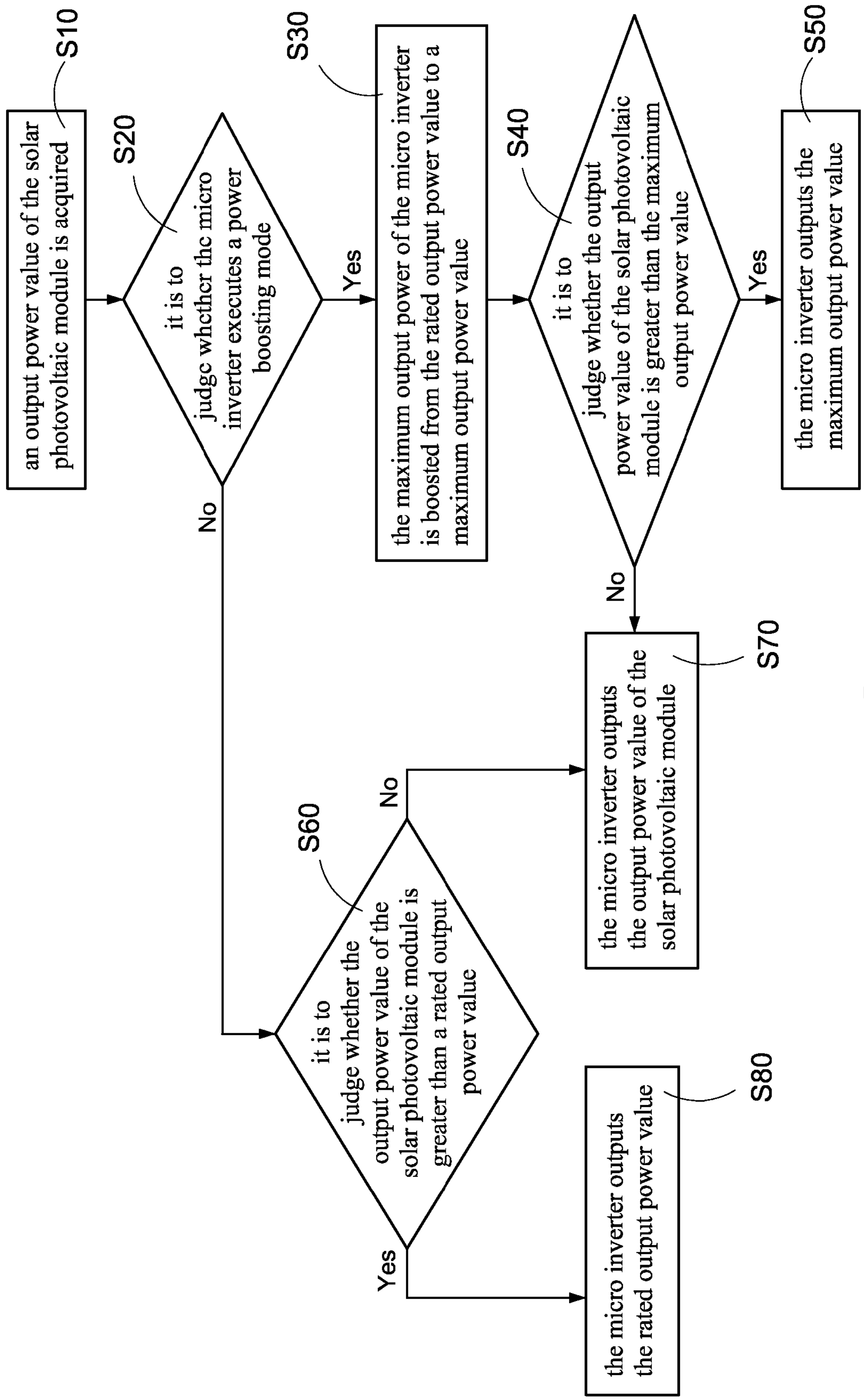

S10
an output power value of the solar photovoltaic module is acquired
S20
it is to judge whether the micro inverter executes a power boosting mode
Yes
No
S30
the maximum output power of the micro inverter is boosted from the rated output power value to a maximum output power value
S40
it is to judge whether the output power value of the solar photovoltaic module is greater than the maximum output power value
Yes
No
S50
the micro inverter outputs the maximum output power value
S60
it is to judge whether the output power value of the solar photovoltaic module is greater than a rated output power value
No
Yes
S70
the micro inverter outputs the output power value of the solar photovoltaic module
S80
the micro inverter outputs the rated output power value

FIG.7

MICRO INVERTER OF SOLAR POWER SYSTEM AND METHOD OF OPERATING THE SAME

BACKGROUND

1. Technical Field

The present disclosure relates generally to a micro inverter of a solar power system and a method of operating the same, and more particularly to a micro inverter with a power boosting function of a solar power system.

2. Description of Related Art

The research and development of alternative energy resources have become the major issue and key polity in many developed countries over the world since the two oil crises of the 1970s. In addition, the oil prices rise because the industrial development promotes the global economic growth and results in the rapid growth of the oil demand. Hence, environmental issues have received more attention recently, and more particularly to the effects of carbon dioxide on air pollution. In order to effectively reduce our dependence on oil as a source of energy, a variety of renewable resources, such as solar energy, wind energy, and so on, are researched and developed.

Because the solar energy has the pollution-free and public harm-free characteristics and is further inexhaustible in supply and always available for use, the solar energy has high potential applications and developments. Recently with the rapidly development of the high-efficiency solar cells, this topic has been gradually promoted by making policies in many developed countries, such as Europe countries, the United States, Japan, and so on.

The conventional common structure of the solar photovoltaic generation system is mainly that the solar photovoltaic module array is in series and/or in parallel. However, the structure of the solar photovoltaic module array has following disadvantages:

It is difficult to consider MPPT function for all in-series or in-parallel solar photovoltaic modules so that the utilization ratio of the solar photovoltaic modules is lower, the influence of the partial shading is serious, and the system expansion is inelastic. In order to overcome the above-mentioned problems, the technology of micro inverters is developed.

Reference is made to FIG. **1** which is a schematic circuit block diagram of a related art solar photovoltaic module and a related art micro inverter. The solar photovoltaic module **10**A generates a solar photovoltaic module output power Pv, and the micro inverter **20**A generates a micro inverter output power Pm. For convenience, the detailed operation of the relationship between the solar photovoltaic module output power Pv and the micro inverter output power Pm is described hereinafter as follows, and reasonable assumed data are exemplified. It is assumed that the rated output power value of the solar photovoltaic module is 250 watts when the ambient temperature around the solar photovoltaic module is 25° C. If the micro inverter **20**A with the 215-watt rated output power value is selected to coordinate with the solar photovoltaic module **10**A, the maximum output power of the micro inverter is merely 215 watts even though the solar photovoltaic module output power Pv is 250 watts. In other words, the redundant output power between the output power value of the solar photovoltaic module **10**A and the rated output power value of the micro inverter **20**A is unavailable so that the utilization ratio of the solar photovoltaic module output power Pv is low. Hence, the better solution to overcome the problem is that the micro inverter **20**A with greater rated output power value is selected to coordinate with the solar photovoltaic module **10**A so that the micro inverter **20**A can completely and fully output the solar photovoltaic module output power Pv, thus increasing the utilization ratio of the solar photovoltaic module output power Pv.

The relationship between the output power value of the solar photovoltaic module **10**A and the ambient temperature is negative temperature coefficient. That is, the output power value of the solar photovoltaic module **10**A is lower when higher ambient temperature around the solar photovoltaic module **10**A. Reference is made to FIG. **2** which is a schematic view of a relationship between the output power value of the solar photovoltaic module and the ambient temperature. Comparing to the above-mentioned example, the solar photovoltaic module output power Pv is 230 watts when the ambient temperature is increased to 40° C.; and also, the solar photovoltaic module output power Pv is 210 watts when the ambient temperature is further increased to 60° C. Therefore, the micro inverter **20**A with the 250-watt rated output power value can completely and fully output the solar photovoltaic module output power Pv whether the ambient temperature is 40° C. or 60° C. so that the utilization ratio of the solar photovoltaic module output power Pv is increased.

On the contrary, the solar photovoltaic module output power Pv is 280 watts when the ambient temperature is reduced to 0° C. Because the micro inverter **20**A with the 250-watt rated output power value is selected to coordinate with the solar photovoltaic module **10**A, the maximum output power of the micro inverter is merely 250 watts even though the solar photovoltaic module output power Pv is 280 watts. In other words, the redundant output power between the output power value of the solar photovoltaic module **10**A and the rated output power value of the micro inverter **20**A is unavailable so that the utilization ratio of the solar photovoltaic module output power Pv is low.

Accordingly, it is desirable to provide a micro inverter of a solar power system and a method of operating the same to increase output power of the micro inverter without increasing additional solar photovoltaic module devices and merely executing a power boosting function according to the feature of the negative temperature coefficient so as to increase power generation efficiency, reduce power generation costs, increase operation adaptation, and widely apply to different regions and countries.

SUMMARY

An object of the present disclosure is to provide a micro inverter of a solar power system to solve the above-mentioned problems. Accordingly, the solar power system has a solar photovoltaic module producing a solar photovoltaic module output power. The micro inverter includes a DC-to-DC converter, a DC-to-AC converter, a temperature sensor, and a microprocessor. The DC-to-DC converter receives a DC voltage generated from the solar photovoltaic module, and produces a DC output voltage. The DC-to-AC converter receives the DC output voltage, and produces a micro inverter output power. The temperature sensor detects an ambient temperature around the solar photovoltaic module, and produces a temperature detection signal. The microprocessor receives the temperature detection signal and a power boosting signal. The microprocessor correspondingly acquires an output power value of the solar photovoltaic module according to the temperature detection signal when the power boosting signal is enabled, and produces a first control signal to control the DC-to-DC converter and produces a second control signal to control the DC-to-AC converter, thus increasing an output power value of the micro inverter.

Another object of the present disclosure is to provide a micro inverter of a solar power system to solve the above-mentioned problems. Accordingly, the solar power system has a solar photovoltaic module producing a solar photovoltaic module output power. The micro inverter includes a DC-to-DC converter, a DC-to-AC converter, a voltage detector, a current detector, and a microprocessor. The DC-to-DC converter receives a DC voltage generated from the solar photovoltaic module, and produces a DC output voltage. The DC-to-AC converter receives the DC output voltage, and produces a micro inverter output power. The voltage detector detects the DC voltage generated from the solar photovoltaic module, and produces a voltage detection signal. The current detector detects a DC current generated from the solar photovoltaic module, and produces a current detection signal. The microprocessor receives the voltage detection signal, the current detection signal, and a power boosting signal. The microprocessor acquires an output power value of the solar photovoltaic module according to a product of the voltage detection signal and the current detection signal when the power boosting signal is enabled, and produces a first control signal to control the DC-to-DC converter and produces a second control signal to control the DC-to-AC converter, thus increasing an output power value of the micro inverter.

Further another object of the present disclosure is to provide a method of operating a micro inverter of a solar power system. The solar power system has a solar photovoltaic module producing a solar photovoltaic module output power. A micro inverter receives the solar photovoltaic module output power and produces a micro inverter output power. The method comprising following steps: (a) acquiring an output power value of the solar photovoltaic module; (b) judging whether the micro inverter executes a power boosting mode; (c) boosting the maximum output power of the micro inverter from a rated output power value to a maximum output power value when the micro inverter executes the power boosting mode; (d) judging whether the output power value of the solar photovoltaic module is greater than the maximum output power value; and (e) outputting the maximum output power value from the micro inverter when the output power value of the solar photovoltaic module is greater than the maximum output power value.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the present disclosure as claimed. Other advantages and features of the present disclosure will be apparent from the following description, drawings and claims.

BRIEF DESCRIPTION OF DRAWINGS

The features of the present disclosure believed to be novel are set forth with particularity in the appended claims. The present disclosure itself, however, may be best understood by reference to the following detailed description of the present disclosure, which describes an exemplary embodiment of the present disclosure, taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic circuit block diagram of a related art solar photovoltaic module and a related art micro inverter;

FIG. **2** is a schematic view of a relationship between the output power value of the solar photovoltaic module and the ambient temperature;

FIG. **3** is a schematic circuit block diagram of a micro inverter of a solar power system according to a first embodiment of the present disclosure;

FIG. **4** is a schematic circuit block diagram in detail of the micro inverter of the solar power system according to the first embodiment of the present disclosure;

FIG. **5** is a schematic circuit block diagram of the micro inverter of the solar power system according to a second embodiment of the present disclosure;

FIG. **6** is a schematic circuit block diagram in detail of the micro inverter of the solar power system according to the second embodiment of the present disclosure; and

FIG. **7** is a flowchart of a method of operating a micro inverter of a solar power system according to the present disclosure.

DETAILED DESCRIPTION

Reference will now be made to the drawing figures to describe the present invention in detail.

Reference is made to FIG. **3** which is a schematic circuit block diagram of a micro inverter of a solar power system according to a first embodiment of the present disclosure. The solar power system provides a solar photovoltaic module output power Pv generated from a solar photovoltaic module **30**, and the solar photovoltaic module output power Pv is converted into a micro inverter output power Pm by the micro inverter **10**. The micro inverter **10** includes a DC-to-DC converter **102**, a DC-to-AC converter **104**, a temperature sensor **106**, and a microprocessor **108**. The DC-to-DC converter **102** receives a DC voltage Vp generated from the solar photovoltaic module **30**, and converts the DC voltage Vp into a DC output voltage Vt. The DC-to-DC converter **102** is substantially a step-up converter to step up the DC voltage Vp. For a 60-cell solar photovoltaic module, the typical value of the DC voltage Vp is about 30 volts and the typical value of the DC output voltage Vt is about 300 volts. Hence, the DC-to-DC converter **102** is provided to step up the 30-volt DC voltage Vp to the 300-volt DC output voltage Vt. The DC-to-AC converter **104** receives the DC output voltage Vt, and converts the DC output voltage Vt into the micro inverter output power Pm. That is, the DC-to-AC converter **104** receives the DC output voltage Vt, and converts the DC output voltage Vt into an AC power source Vac for supplying power to the rear-end load or electric grid. The temperature sensor **106** detects an ambient temperature Ta around the solar photovoltaic module **30**, and produces a temperature detection signal St. The microprocessor **108** receives the temperature detection signal St and a power boosting signal Spb. When the boosting signal Spb is enabled, the microprocessor **108** acquires the solar photovoltaic module output power Pv according to the temperature detection signal St to produce a first control signal **S1** and a second control signal S**2**. The first control signal **S1** is provided to control the DC-to-DC converter **102** and the second control signal S**2** is provided to control the DC-to-AC converter **104** so as to increase the micro inverter output power Pm. Especially, the power boosting signal Spb is produced inside the micro inverter **10**, but not limited. Also, the power boosting signal Spb can be generated by an external mechanism and provided to the micro inverter **10** according to the actual operation requirements for the user. In addition, the micro inverter **10** further includes an auxiliary power unit **110**. The auxiliary power unit **110** receives the DC voltage Vp, and converts the DC voltage Vp into at least one DC output voltage, such as 12-volt, 5-volt, or 3.3-volt DC output voltage to be an operation voltage Vau for supplying the microprocessor **108**. The detailed operation of power boosting of the micro inverter **10** will be described hereinafter as follows.

Reference is made to FIG. **4** which is a schematic circuit block diagram in detail of the micro inverter of the solar power system according to the first embodiment of the present disclosure. The microprocessor **108** has a comparison unit **1081**, a judgment unit **1082**, a first control signal generation unit **1083**, and a second control signal generation unit **1084**. The comparison unit **1081** receives the temperature detection signal St, and produces an output power comparison signal Pvt. The judgment unit **1082** receives the output power comparison signal Pvt, the power boosting signal Spb, a rated output power value Pmr, and a maximum output power value Pmm to produce a driving signal Sd. In particular, the rated output power value Pmr and the maximum output power value Pmm are determined according to internal circuit components of the micro inverter **10**. In other words, the upper limit value of the output power of the micro inverter **10** is boosted to the maximum output power value Pmm after the micro inverter **10** executes the power boosting mode. Also, the maximum output power value Pmm is determined according to internal circuit components of the micro inverter **10**. The first control signal generation unit **1083** receives the driving signal Sd, and produces the first control signal **S1** so as to control the DC-to-DC converter **102**. The second control signal generation unit **1084** receives the driving signal Sd, and produces the second control signal **S2** so as to control the DC-to-AC converter **104**. In particular, the first control signal generation unit **1083** and the second control signal generation unit **1084** are a PWM signal generator, respectively; and the first control signal **S1** and the second control signal **S2** are a PWM signal, respectively.

When the power boosting signal Spb is enabled, the driving signal Sd controls the first control signal generation unit **1083** or the second control signal generation unit **1084** to boost the maximum output power of the micro inverter **10** from the rated output power value Pmr to the maximum output power value Pmm. In particular, the micro inverter **10** outputs the maximum output power value Pmm when the output power value of the solar photovoltaic module **30** is greater than the maximum output power value Pmm. The micro inverter **10** outputs the output power value of the solar photovoltaic module **30** when the output power value of the solar photovoltaic module **30** is less than or equal to the maximum output power value Pmm.

When the power boosting signal Spb is disabled, the maximum output power of the micro inverter **10** is the rated output power value Pmr. In particular, the micro inverter **10** outputs the rated output power value Pmr when the output power value of the solar photovoltaic module **30** is greater than the rated output power value Pmr. The micro inverter **10** outputs the output power value of the solar photovoltaic module **30** when the output power value of the solar photovoltaic module **30** is less than or equal to the rated output power value Pmr. In particular, the user can determine whether the power boosting mode is executed or not, that is, the micro inverter is operated in the normal power mode or the power boosting mode according to the actual requirements. More specifically, one pin of the microprocessor can be used for operating the power boosting mode, that is, the user can control the pin in high level or low level to enable or disable the power boosting mode. Furthermore, the power boosting mode can be controlled by the power boosting signal Spb transmitted through the power line communication (PLC).

Reference is made to FIG. **5** which is a schematic circuit block diagram of the micro inverter of the solar power system according to a second embodiment of the present disclosure. The solar power system provides a solar photovoltaic module output power Pv generated from a solar photovoltaic module **30**, and the solar photovoltaic module output power Pv is converted into a micro inverter output power Pm by the micro inverter **20**. The micro inverter **20** includes a DC-to-DC converter **202**, a DC-to-AC converter **204**, a voltage detector **206**, a current detector **208**, and a microprocessor **210**. The DC-to-DC converter **202** receives a DC voltage Vp generated from the solar photovoltaic module **30**, and converts the DC voltage Vp into a DC output voltage Vt. The DC-to-DC converter **202** is substantially a step-up converter to step up the DC voltage Vp. For a 60-cell solar photovoltaic module, the typical value of the DC voltage Vp is about 30 volts and the typical value of the DC output voltage Vt is about 300 volts. Hence, the DC-to-DC converter **202** is provided to step up the 30-volt DC voltage Vp to the 300-volt DC output voltage Vt. The DC-to-AC converter **204** receives the DC output voltage Vt, and converts the DC output voltage Vt into the micro inverter output power Pm. That is, the DC-to-AC converter **204** receives the DC output voltage Vt, and converts the DC output voltage Vt into an AC power source Vac for supplying power to the rear-end load or electric grid. The voltage detector **206** detects the DC voltage Vp generated from the solar photovoltaic module **30**, and produces a voltage detection signal Sv. The current detector **208** detects a DC current Ip generated from the solar photovoltaic module **30**, and produces a current detection signal Si. The microprocessor **210** receives the voltage detection signal Sv, the current detection signal Si, and a power boosting signal Spb. When the boosting signal Spb is enabled, the microprocessor **210** acquires an output power value of the solar photovoltaic module according to a product of the voltage detection signal Sv and the current detection signal Si, and produces a first control signal **S1** to control the DC-to-DC converter **202** and produces a second control signal **S2** to control the DC-to-AC converter **204**, thus increasing an output power value of the micro inverter Pm. In addition, the micro inverter **20** further includes an auxiliary power unit **212**. The auxiliary power unit **212** receives the DC voltage Vp, and converts the DC voltage Vp into at least one DC output voltage, such as 12-volt, 5-volt, or 3.3-volt DC output voltage to be an operation voltage Vau for supplying the microprocessor **210**. The detailed operation of power boosting of the micro inverter **20** will be described hereinafter as follows.

Reference is made to FIG. **6** which is a schematic circuit block diagram in detail of the micro inverter of the solar power system according to the second embodiment of the present disclosure. The microprocessor **210** has a multiplication unit **2101**, a judgment unit **2102**, a first control signal generation unit **2103**, and a second control signal generation unit **2104**. The multiplication unit **2101** receives the voltage detection signal Sv and the current detection signal Si, and calculates the product of the voltage detection signal Sv and the current detection signal Si, thus producing an output power calculation signal Pvc. The judgment unit **2102** receives the output power calculation signal Pvc, the power boosting signal Spb, a rated output power value Pmr, and a maximum output power value Pmm to produce a driving signal Sd. In particular, the rated output power value Pmr and the maximum output power value Pmm are determined according to internal circuit components of the micro inverter **20**. In other words, the upper limit value of the output power of the micro inverter **20** is boosted to the maximum output power value Pmm after the micro inverter **20** executes the power boosting mode. Also, the maximum output power value Pmm is determined according to internal circuit components of the micro inverter **20**. The first control signal generation unit **2103** receives the driving signal Sd, and produces the first control signal **S1** so as to control the DC-to-DC converter **202**. The second control signal generation unit **2104** receives the driving signal Sd, and produces the second control signal S**2** so as to control the DC-to-AC converter **204**. In particular, the first control signal generation unit **2103** and the second control signal generation unit **2104** are a PWM signal generator, respectively; and the first control signal S**1** and the second control signal S**2** are a PWM signal, respectively.

When the power boosting signal Spb is enabled, the driving signal Sd controls the first control signal generation unit **2103** or the second control signal generation unit **2104** to boost the maximum output power of the micro inverter **20** from the rated output power value Pmr to the maximum output power value Pmm. In particular, the micro inverter **20** outputs the maximum output power value Pmm when the output power value of the solar photovoltaic module **30** is greater than the maximum output power value Pmm. The micro inverter **20** outputs the output power value of the solar photovoltaic module **30** when the output power value of the solar photovoltaic module **30** is less than or equal to the maximum output power value Pmm.

When the power boosting signal Spb is disabled, the maximum output power of the micro inverter **20** is the rated output power value Pmr. In particular, the micro inverter **20** outputs the rated output power value Pmr when the output power value of the solar photovoltaic module **30** is greater than the rated output power value Pmr. The micro inverter **20** outputs the output power value of the solar photovoltaic module **30** when the output power value of the solar photovoltaic module **30** is less than or equal to the rated output power value Pmr. In particular, the user can determine whether the power boosting mode is executed or not, that is, the micro inverter is operated in the normal power mode or the power boosting mode according to the actual requirements. More specifically, one pin of the microprocessor can be used for operating the power boosting mode, that is, the user can control the pin in high level or low level to enable or disable the power boosting mode. Furthermore, the power boosting mode can be controlled by the power boosting signal Spb transmitted through the power line communication (PLC).

Reference is made to FIG. **7** which is a flowchart of a method of operating a micro inverter of a solar power system according to the present disclosure. The solar power system has a solar photovoltaic module producing a solar photovoltaic module output power. A micro inverter receives the solar photovoltaic module output power and produces a micro inverter output power. The method of operating the micro inverter has following steps. First, an output power value of the solar photovoltaic module is acquired (S**10**). In particular, data of relationship between output power values of the solar photovoltaic module and ambient temperatures around the solar photovoltaic module are record in a lookup table, and the output power value of the solar photovoltaic module corresponding to the ambient temperature is acquired based on the recorded data in the lookup table. Also, the ambient temperature around the solar photovoltaic module is detected by a temperature sensor. In addition, the output power value of the solar photovoltaic module is acquired by calculating a product of the DC voltage and the DC current generated from the solar photovoltaic module. Also, the DC voltage and the DC current are detected by a voltage detector and a current detector, respectively. Afterward, it is to judge whether the micro inverter executes a power boosting mode (also called an energy boosting mode) (S**20**). In particular, the user can determine whether the power boosting mode is executed or not, that is, the micro inverter is operated in the normal power mode or the power boosting mode according to the actual requirements. The detailed operation of normal power mode or the power boosting mode of the micro inverter will be described hereinafter as follows. After the step (S**20**), if the power boosting mode is not executed, it is to judge whether the output power value of the solar photovoltaic module is greater than a rated output power value (S**60**). In particular, the rated output power value is the active power outputted from the micro inverter for a long time under the stable operation. On the contrary, after the step (S**20**), if the power boosting mode is executed, the maximum output power of the micro inverter is boosted from the rated output power value to a maximum output power value (S**30**). Especially, the maximum output power of the micro inverter is the rated output power value when the micro inverter is operated in the normal power mode; the maximum output power of the micro inverter is the maximum output power value when the micro inverter is operated in the power boosting mode.

After the step (S**30**), it is to judge whether the output power value of the solar photovoltaic module is greater than the maximum output power value (S**40**). If the output power value of the solar photovoltaic module is greater than the maximum output power value, the micro inverter outputs the maximum output power value (S**50**). On the contrary, the micro inverter outputs the output power value of the solar photovoltaic module if the output power value of the solar photovoltaic module is less than or equal to the maximum output power value (S**70**). After the step (S**60**), if the output power value of the solar photovoltaic module is less than or equal to the rated output power value, the step (S**70**) is executed. On the contrary, if the output power value of the solar photovoltaic module is greater than the rated output power value, the micro inverter outputs the rated output power value (S**80**).

For convenience, the detailed operation of the micro inverter of the solar power system is described hereinafter as follows, and reasonable assumed data are exemplified. It is assumed that the output power value of the solar photovoltaic module is 250 watts when the ambient temperature around the solar photovoltaic module is 25° C. Because of the relationship between the output power value of the solar photovoltaic module and the ambient temperature is negative temperature coefficient, it is assumed that the output power value of the solar photovoltaic module is 280 watts when the ambient temperature around the solar photovoltaic module is 0° C., and the output power value of the solar photovoltaic module is 320 watts when the ambient temperature around the solar photovoltaic module is −30° C. In addition, it is assumed that the rated output power value of the micro inverter is 250 watts; also the maximum output power of the micro inverter is boosted from the 250 watts (the rated output power value) to 300 watts (the maximum output power value) when the power boosting mode is executed.

Based on the above-mentioned reasonable assumed data, three different output power values of the solar photovoltaic module are exemplified but are not intended to limit the scope of the disclosure.

(1) It is assumed that the output power value of the solar photovoltaic module is 230 watts. Correspondingly, the ambient temperature around the solar photovoltaic module is about 45° C. According to the relationship between the output power value and the ambient temperature, which can be recorded in a lookup table, the output power value of the solar photovoltaic module can be estimated to be 230 watts. In addition, the output power value of the solar photovoltaic module can also calculated by the DC voltage and the DC current generated from the solar photovoltaic module. Because the output power value (230 watts) of the solar photovoltaic module is less than or equal to the rated output

power value (250 watts), the micro inverter outputs the output power value of the solar photovoltaic module (**230**) whether the power boosting mode is executed or not.

(2) It is assumed that the output power value of the solar photovoltaic module is 280 watts. Correspondingly, the ambient temperature around the solar photovoltaic module is about 0° C. According to the relationship between the output power value and the ambient temperature, which can be recorded in a lookup table, the output power value of the solar photovoltaic module can be estimated to be 280 watts. In addition, the output power value of the solar photovoltaic module can also calculated by the DC voltage and the DC current generated from the solar photovoltaic module. Because the output power value (280 watts) of the solar photovoltaic module is greater than the rated output power value (250 watts), the micro inverter outputs the rated output power value (250) if the power boosting mode is not executed. On the contrary, the maximum output power of the micro inverter is boosted from the 250 watts (the rated output power value) to 300 watts (the maximum output power value) if the power boosting mode is executed. However, the micro inverter outputs the output power value (280 watts) of the solar photovoltaic module because the output power value (280 watts) of the solar photovoltaic module is less than or equal to the maximum output power value (300 watts). That is, the output power value of the solar photovoltaic module can be completely and fully outputted through the micro inverter because the power boosting mode is executed.

(3) It is assumed that the output power value of the solar photovoltaic module is 320 watts. Correspondingly, the ambient temperature around the solar photovoltaic module is about −30° C. According to the relationship between the output power value and the ambient temperature, which can be recorded in a lookup table, the output power value of the solar photovoltaic module can be estimated to be 320 watts. In addition, the output power value of the solar photovoltaic module can also calculated by the DC voltage and the DC current generated from the solar photovoltaic module. Because the output power value (320 watts) of the solar photovoltaic module is greater than the rated output power value (250 watts), the micro inverter outputs the rated output power value (250) if the power boosting mode is not executed. On the contrary, the maximum output power of the micro inverter is boosted from the 250 watts (the rated output power value) to 300 watts (the maximum output power value) if the power boosting mode is executed. However, the micro inverter outputs the maximum output power value (300 watts) because the output power value (320 watts) of the solar photovoltaic module is greater than the maximum output power value (300 watts). That is, the output power value of the solar photovoltaic module can be boosted from the rated output power value to the maximum output power value because the power boosting mode is executed.

In conclusion, the present disclosure has following advantages:

1. Because of the relationship between the output power value of the solar photovoltaic module and the ambient temperature is negative temperature coefficient, the power boosting mode can be implemented so that the solar photovoltaic module can output more power under the low-temperature environment;

2. One pin of the microprocessor can be used for operating the power boosting mode, that is, the user can control the pin in high level or low level to enable or disable the power boosting mode. If the power boosting mode is not executed, the micro inverter is operated in the normal power mode; if the power boosting mode is executed, the maximum output power of the micro inverter is boosted from the rated output power value to a maximum output power value;

3. The micro inverter can output more power without increasing additional solar photovoltaic module devices when the power boosting mode is executed, thus increasing utilization ratio and improving power generation efficiency under the same power generation costs;

4. Because the power boosting mode is implemented, the micro inverter with the smaller or appropriate rated output power can be used to coordinate the solar photovoltaic module. The output power of the micro inverter can be boosted by executing the power boosting mode, thus recusing equipment costs and increasing operation adaptation; and

5. The solar photovoltaic module coordinated with the micro inverter with the power-boosting function can be widely applied to different regions and countries, and more particularly to extremely cold regions and countries so as to significantly increase the value of the power boosting function.

Although the present disclosure has been described with reference to the preferred embodiment thereof, it will be understood that the present disclosure is not limited to the details thereof. Various substitutions and modifications have been suggested in the foregoing description, and others will occur to those of ordinary skill in the art. Therefore, all such substitutions and modifications are intended to be embraced within the scope of the present disclosure as defined in the appended claims.

What is claimed is:

1. A micro inverter of a solar power system, the solar power system having a solar photovoltaic module producing a solar photovoltaic module output power, the micro inverter comprising: a DC-to-DC converter configured to receive a DC voltage generated from the solar photovoltaic module, and produce a DC output voltage; a DC-to-AC converter configured to receive the DC output voltage, and produce a micro inverter output power; a temperature sensor configured to detect an ambient temperature around the solar photovoltaic module, and produce a temperature detection signal; and a microprocessor configured to receive the temperature detection signal and a power boosting signal; wherein the microprocessor is configured to correspondingly acquire an output power value of the solar photovoltaic module according to the temperature detection signal when the power boosting signal is enabled, and produce a first control signal to control the DC-to-DC converter and produce a second control signal to control the DC-to-AC converter, thus increasing an output power value of the micro inverter; the microprocessor comprising: a comparison unit configured to receive the temperature detection signal, and produce an output power comparison signal; a judgment unit configured to receive the output power comparison signal, the power boosting signal, and the output power value of the micro inverter to produce a driving signal; a first control signal generation unit configured to receive the driving signal, and produce the first control signal; and a second control signal generation unit configured to receive the driving signal, and produce the second control signal; wherein the driving signal is configured to control the first control signal generation unit or the second control signal generation unit to boost the maximum output power of the micro inverter from a rated output power value to a maximum output power value when the power boosting signal is enabled; when the output power value of the solar photovoltaic module is greater than the maximum output power value, the micro inverter is configured to output the maximum output power value; or when the output power value of the solar photovoltaic module is less than or equal to the maximum output power value, the micro inverter is configured to output the output power value of the solar photovoltaic module.

2. The micro inverter of the solar power system in claim **1**, wherein the maximum output power of the micro inverter is a rated output power value when the power boosting signal is disabled; when the output power value of the solar photovoltaic module is greater than the rated output power value, the micro inverter is configured to output the rated output power value; when the output power value of the solar photovoltaic module is less than or equal to the rated output power value, the micro inverter is configured to output the output power value of the solar photovoltaic module.

3. The micro inverter of the solar power system in claim **1**, wherein the comparison unit is a lookup table, and the comparison unit is configured to record data of relationship between output power values of the solar photovoltaic module and ambient temperatures around the solar photovoltaic module; the ambient temperature is correspondingly detected according to the temperature detection signal, and the output power value of the solar photovoltaic module corresponding to the ambient temperature is acquired based on the recorded data in the lookup table.

4. The micro inverter of the solar power system in claim **1**, wherein the rated output power value and the maximum output power value are determined according to internal circuit components of the micro inverter.

5. The micro inverter of the solar power system in claim **1**, wherein the micro inverter further comprises:

an auxiliary power unit configured to receive the DC voltage, and convert the DC voltage to produce at least one operation voltage for the microprocessor.

6. A micro inverter of a solar power system, the solar power system having a solar photovoltaic module producing a solar photovoltaic module output power, the micro inverter comprising: a DC-to-DC converter configured to receive a DC voltage generated from the solar photovoltaic module, and produce a DC output voltage; a DC-to-AC converter configured to receive the DC output voltage, and produce a micro inverter output power; a voltage detector configured to detect the DC voltage generated from the solar photovoltaic module, and produce a voltage detection signal; a current detector configured to detect a DC current generated from the solar photovoltaic module, and produce a current detection signal; and a microprocessor configured to receive the voltage detection signal, the current detection signal, and a power boosting signal; wherein the microprocessor is configured to acquire an output power value of the solar photovoltaic module according to a product of the voltage detection signal and the current detection signal when the power boosting signal is enabled, and produce a first control signal to control the DC-to-DC converter and produce a second control signal to control the DC-to-AC converter, thus increasing an output power value of the micro inverter; the microprocessor comprising: a multiplication unit configured to receive the voltage detection signal and the current detection signal, and calculate the product of the voltage detection signal and the current detection signal, thus producing an output power calculation signal; a judgment unit configured to receive the output power calculation signal, the power boosting signal, and the output power value of the micro inverter to produce a driving signal; a first control signal generation unit configured to receive the driving signal, and produce the first control signal; and a second control signal generation unit configured to receive the driving signal, and produce the second control signal; wherein the driving signal is configured to control the first control signal generation unit or the second control signal generation unit to boost the maximum output power of the micro inverter from a rated output power value to a maximum output power value when the power boosting signal is enabled; when the output power value of the solar photovoltaic module is greater than the maximum output power value, the micro inverter is configured to output the maximum output power value; or when the output power value of the solar photovoltaic module is less than or equal to the maximum output power value, the micro inverter is configured to output the output power value of the solar photovoltaic module.

7. The micro inverter of the solar power system in claim **6**, wherein the maximum output power of the micro inverter is a rated output power value when the power boosting signal is disabled; when the output power value of the solar photovoltaic module is greater than the rated output power value, the micro inverter is configured to output the rated output power value; when the output power value of the solar photovoltaic module is less than or equal to the rated output power value, the micro inverter is configured to output the output power value of the solar photovoltaic module.

8. The micro inverter of the solar power system in claim **6**, wherein the rated output power value and the maximum output power value are determined according to internal circuit components of the micro inverter.

9. The micro inverter of the solar power system in claim **6**, wherein the micro inverter further comprises:

an auxiliary power unit configured to receive the DC voltage, and convert the DC voltage to produce at least one operation voltage for the microprocessor.

10. A method of operating a micro inverter of a solar power system, the solar power system having a solar photovoltaic module producing a solar photovoltaic module output power; a micro inverter configured to receive the solar photovoltaic module output power and produce a micro inverter output power, the method comprising the following steps: (a) acquiring an output power value of the solar photovoltaic module; (b) judging whether the micro inverter executes a power boosting mode; (c)(i) boosting the maximum output power of the micro inverter from a rated output power value to a maximum output power value when the micro inverter executes the power boosting mode; or (c)(ii) if the micro inverter does not execute the power boosting mode, judging whether the output power value of the solar photovoltaic module is greater than the rated output power value, and either: outputting the output power value of the solar photovoltaic module from the micro inverter when the output power value of the solar photovoltaic module is less than or equal to the rated output power value, or outputting the rated output power value from the micro inverter when the output power value of the solar photovoltaic module is greater than the rated output power value; (d) judging whether the output power value of the solar photovoltaic module is greater than the maximum output power value; and (e) outputting the maximum output power value from the micro inverter when the output power value of the solar photovoltaic module is greater than the maximum output power value.

11. The method of operating the micro inverter of the solar power system in claim **10**, wherein after the step (d), the method comprises following step:

outputting the output power value of the solar photovoltaic module from the micro inverter when the output power value of the solar photovoltaic module is less than or equal to the maximum output power value.

12. The method of operating the micro inverter of the solar power system in claim **10**, wherein in the step (a), data of relationship between output power values of the solar photovoltaic module and ambient temperatures around the solar photovoltaic module are record in a lookup table, and the output power value of the solar photovoltaic module corresponding to the ambient temperature is acquired based on the recorded data in the lookup table.

13. The method of operating the micro inverter of the solar power system in claim **12**, wherein the ambient temperature around the solar photovoltaic module is detected by a temperature sensor.

14. The method of operating the micro inverter of the solar power system in claim **10**, wherein in the step (a), the output power value of the solar photovoltaic module is acquired by calculating a product of the DC voltage and the DC current generated from the solar photovoltaic module.

* * * * *